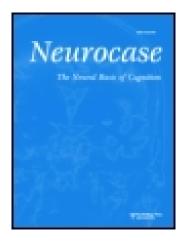
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### A left basal ganglia case of dynamic aphasia or impairment of extra-language cognitive processes?

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# A left basal ganglia case of dynamic aphasia or impairment of extra-language cognitive processes?

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We report the case of OTM who presented with dynamic aphasia following a stroke that occurred in the left basal ganglia. He showed drastically reduced spontaneous speech in the context of well preserved naming, repetition and comprehension skills. OTM was particularly impaired in generating words, sentences and phrases when cued by a stimulus allowing many response options. By contrast, when a single response was strongly suggested by a stimulus, he could generate verbal responses adequately. OTM's non-verbal response generation abilities varied across tasks. He performed in the normal range in a motor movement generation test and he produced as many figures as controls when tested on a figural fluency task. He showed, however, many perseverations on this test. Moreover in a random number generation task he produced more responses that were part of ascending and descending series of numbers. The patient's impairments are interpreted as a consequence of two deficits. The first of these consists of an inability to generate verbal responses particularly in situations of high competition and involves the function of left frontal regions. The second deficit is one of impaired novel thought generation as evidenced by perseverations. This second deficit has been proposed to be a function of basal ganglia damage.

Keywords: Dynamic aphasia; Failure of inhibition; Verbal alternatives; Basal ganglia; Cortical-subcortical loops.

#### INTRODUCTION

Dynamic aphasia consists of an impairment in propositional language production characterized by an exceptionally reduced spontaneous speech in the context of well-preserved naming, articulation, prosody and repetition skills. Patients with dynamic aphasia have great difficulty in the initiation and elaboration of self-generated utterances. Nevertheless they may be able to describe pictures and to answer certain types of direct questions (Luria, 1970). Dynamic aphasia generally occurs after lesions confined to the left cerebral hemisphere specifically involving frontal regions (see Robinson, Shallice, & Cipolotti, 2005, for a review). Both neurodegenerative disorders and focal lesions have been reported to cause this disorder.

Recently several theoretical accounts for dynamic aphasia have been proposed; most of these accounts interpret such a syndrome within the domain of language while other explanations extend beyond this domain. Among the accounts that interpret dynamic aphasia within the domain of language, some consider the disorder as due to a specific impairment in creating preverbal messages, following the theoretical framework proposed by Levelt (1989, 1999). Preverbal messages

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© 2008 Psychology Press, an imprint of the Taylor & Francis Group, an Informa business http://www.psypress.com/neurocase DOI: 10.1080/13554790802108380 consist of conceptual structures expressed in term of lexical concepts, which are in turn associated with the corresponding words in the language. For example, Warren, Warren, Fox, and Warrington (2003) described a patient (ADY) with a frontal lobe dementia who was impaired when asked to combine various lexical concepts in order to create a new sentence or a phrase, and particularly when required to retrieve lexical concepts from among others or when asked to link them in new ways.

A similar interpretation has also been advocated by Robinson et al. (2005) to account for the language disturbances shown by patient CH who presented with focal atrophy to the left frontal lobe. CH showed a defective conceptual preparation of language, which was particularly evident when lexical concepts had to be generated under conditions of high competition, that is, by choosing them from among others equally plausible such as when a subject has to complete a sentence that can be completed in many different ways. According to Robinson et al. (2005) when stimuli activate many verbal response options, selection between them cannot be accomplished by a damaged system; nevertheless, an appropriate response can be produced when lexical concepts are strongly suggested by the context, namely in conditions of low competition. CH's impairment was shown to be specific to the language domain since an accurate examination of his non-verbal generation abilities showed that these were intact. Robinson, Blair, and Cipolotti (1998) also reported the case of the patient ANG who was seen to be impaired in the selection of a verbal response when there were many competing options.

As stated before, dynamic aphasia has also been held to occur due to impairments extending beyond the domain of language. For instance Raymer, Rowland, Haley, and Crosson (2002) suggested that the deficits observed in case of dynamic aphasia may also involve the ability to produce non-verbal responses. In a similar fashion Robinson, Shallice, and Cipolotti (2006) reported the case of a patient with progressive supranuclear palsy (PSP) who, despite his propositional language impairment, performed well on word and sentence level generation tasks that required a single response, but did not do so in non-verbal generation tasks. Following a discourse level generation analysis, Robinson et al. (2006) claimed that their patient (KAS) was defective in the generation of a "fluent sequence of novel thought" (Robinson et al., 2006, p. 1344). These authors drew a distinction between two subtypes of dynamic aphasia. They argued that patients that present with word and sentence level generation deficits have language specific impairment and generally left inferior frontal gyrus lesions. By contrast, the second type of dynamic aphasia could be associated with bilateral frontal and subcortical damage; the patients affected by this second subtype should present with verbal–non-verbal generation deficits as well as with problems with discourse level generation tests. The authors also claimed that such patients are supposed to be unimpaired in the word and sentence level generation tests.

In explaining the dynamic aphasia suffered by a patient (CO) who had a bilateral striatocapsular infarction, Gold et al. (1997) stressed the importance of the circuit from the dorsolateral prefrontal cortex to the dorsolateral caudate (Alexander & Crutcher, 1990). The authors claimed that a damage to this circuit caused decreased spontaneous speech in their patient, difficulties in executive functions and, most importantly, also an inability to adopt effective strategies for the retrieval of information from the semantic network. CO was a rare case of dynamic aphasia following a subcortical lesion.

The fact that impairments in executive functioning can be found even in non-demented patients suffering from subcortical lesions has also recently been explained as due to disturbance of subcorticalfrontal circuits (Kramer, Reed, Mungas, Weiner, & Chui, 2002). According to this view, subcortical ischemic vascular lesions would cause the disruption of dorsolateral prefrontal-subcortical circuits and produce signs of dysexecutive syndrome.

However, the functional role of subcortical structures in language and aphasia remains unclear. Some authors (e.g., Alexander, Naeser, & Palumbo, 1987) have suggested that the basal ganglia may not be involved in language at all, though they do recognize a role for some pathways within the white matter. In a related fashion, Nadeau and Crosson (1997) discussed four possible accounts of subcortical aphasia involving structures other than the thalamus, namely those of (a) diaschisis, (b) direct involvement of basal ganglia structures in language processes, (c) disconnection of cortical structures involved in language, and (d) deregulation of release of cortically formulated language segments. They argued that these mechanisms do not easily account for the high degree of heterogeneity in language impairment following subcortical lesions to structures other than the thalamus. They proposed instead that cortical hypoperfusion, which often follows striato-capsular infarction, may be the crucial factor. Nadeau and Crosson (1997) also argue that neither the caudate nor the putamen play a critical role in language.

More recently, Hillis et al. (2002) have stressed the importance of cortical hypoperfusion in the explanation of the language deficits of patients with subcortical stroke. These authors tested a population of 115 patients within 24 h of onset or progression of stroke symptoms for aphasia or hemispatial neglect. Many of these patients (44) only had subcortical infarcts. The authors used some imaging techniques that allow the assessment of the structural lesion and also an evaluation of the functional lesion in early stroke. Such techniques were diffusion-weighted imaging (DWI) and perfusionweighted imaging (PWI). Hillis et al. (2002) also studied whether the restoration of perfusion to the cortex was reflected in the resolution of aphasia. The authors found that most of the patients who only left hemisphere subcortical lesions had suffered from aphasia and that all patients also had cortical hypoperfusion; according to Hillis and colleagues, this suggested that the language deficits suffered by the patients with subcortical lesions could be explained by cortical hypoperfusion. Finally, these authors also showed that the small group of patients which benefited from reversal of cortical hypoperfusion also showed resolution of aphasia.

The evidence reported above suggests that cortical hypoperfusion plays an important role in the aphasic deficits of patients with subcortical lesions; however, this evidence does not completely exclude the possibility that subcortical lesions can more directly cause language deficits. In fact, a more direct role of basal ganglia in language has been proposed by others. Grossman, Stern, Gollomp, Vernon, and Hurtig (1994) reported a verb-learning impairment in Parkinson's disease (PD) patients. In this study, some PD patients were administered a verb-learning task in the context of a forcedchoice sentence picture-matching task. These patients were seen to have a deficit in "appreciating grammatical information represented in the new verb" (Grosmann et al., 1994, p. 413). Ullman et al. (1997) reported evidence for a role of basal ganglia structures in grammatical processing. They found a correlation between the right-sided hypokinesia of PD patients and their difficulties in the production of regular English past tense. Ullman et al. (1997) claimed that "one kind of basal ganglia lesion, which leads to the suppression of motor activity (Parkinson's disease), also led to the suppression of rule use" (Ullman et al., 1997, p. 274). A specific role for the striatum in the application of linguistic rules has recently been proposed by Teichmann, Dupoux, Kouider, and Bachoud-Lévi (2006) in a population of Huntington's disease (HD) patients. These patients were administered a task of acceptability judgments of conjugated verbs and nonword forms and a task of lexical decision, and were found to be impaired in rule application while presenting preserved lexical abilities.

An involvement of basal ganglia structures in lexical-semantic processing has also been proposed following studies on patients with subcortical lesions. Copland, Chenery, and Murdoch (2000a; see also Copland, Chenery, & Murdoch, 2000b) tested a group of 14 patients with chronic nonthalamic subcortical (NS) lesions using both standard aphasia batteries (The Western Aphasia Battery, WAB; The Boston Naming Test, BNT) and tests that tap more complex language functions (Test of Language Competence-Expanded Edition, TLC-E; Test of Word Knowledge, TOWK). These authors found that their patients performed as well as normal controls on standard aphasia tests. The exception was given by word fluency in which most of the patients were impaired. Eight patients also had problems in the BNT test. However, when assessed on more complex language functions (TLC-E and TOWK) the NS patients showed impaired performance on all the subtests (the only exception was the Making inferences subtest of the TLC-E where only two patients were impaired). According to Copland and colleagues, the tests on which the NS patients had the greatest difficulties required lexical-semantic manipulation, use of language strategies, cognitive-linguistic flexibility as well as the ability to select between alternative solutions for the same linguistic input. The authors proposed that NS lesions impair the operations of the lexicalsemantic system, in particular generative language and the interpretation of meaning at sentence level (Copland et al., 2000a, p. 6). Importantly, Copland and colleagues argued that their findings were consistent with the proposal (see Wallesch & Papagno, 1988) according to which basal ganglia, and more generally the fronto-striatal loops, have a role in the process of selection of relevant lexical items and in the inhibition of irrelevant ones.

Copland (2003) provided further evidence for a related position, through a semantic priming study. Patients with nonthalamic subcortical vascular

lesions (NS), Parkinson's disease patients (PD), patients with cortical lesions, and controls were required to perform lexical decisions to targets, which were either nonwords or words that were related or not to the prime. They were administered auditory prime-target pairs of four different types (subordinate unrelated, bat-river; dominant unrelated, foot-money; subordinate related, bankriver and dominant related, bank-money). There were two conditions of prime-target interstimulus interval (ISI; short, 200 ms, and long, 1250 ms). In neither NS nor PD patients was there a selective semantic facilitation of the dominant meaning at long ISI. The authors suggested that damage to frontal-subcortical systems led to impaired controlled lexical processing in these patients. In particular, they claimed that dysfunction in the basal ganglia produced impairments in the selective engagement of the semantic network due to damaged inhibitory mechanisms.

Further evidence for the involvement of basal ganglia in lexical processes comes also from neuroimaging studies. In an fMRI experiment, Crosson et al. (2003) administered 4 tasks to 21 subjects: generation of nonsense syllables, generation of words given a rhyming word, generation of words given a semantic category in two conditions: at a slow rate and at a fast rate. They found an involvement of the left pre-supplementary motor area (pre-SMA), dorsal caudate nucleus and ventral anterior thalamic circuit in lexical retrieval, since some of these brain areas were active while subjects performed word generation from rhyming words and from category but, on the other hand, were silent during nonsense syllable generation. According to Crosson et al. (2003), subcortical structures have the function of maintaining a bias towards a lexical alternative chosen from among others in competition during controlled word selection. The role of basal ganglia structures in the attention-controlled access to lexical-semantic information has been proposed by Longworth, Keenan, Barker, Marslen-Wilson, and Tyler (2005) not to be specific to language. These authors have argued that patients with lesions to the basal ganglia might have separate but parallel deficits in semantic and syntactic processes. However, they proposed that such deficits may reflect an impairment of a function involved in language comprehension and production which is not specific to language, namely that of inhibition of competing alternatives during later controlled processes.

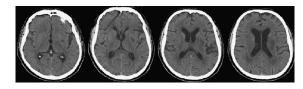


Figure 1. OTM's CT scan. Four images are presented in radiological convention (left hemisphere on the right; see text for details on the lesion).

In this study we report the case of patient OTM who was classified as a dynamic aphasic following a vascular accident to his left basal ganglia (see Figure 1). Together with his language output disorder OTM presented with many signs of executive dysfunction. In this respect our case shows similarities with that reported by Gold et al. (1997). However, Gold et al.'s patient was not given tasks to investigate the level of competition in the response set of the type used by Robinson et al. (1998, 2005, 2006). In the present study, we present a patient with subcortical damage defined with a series of tasks commonly used with other dynamic aphasic patients. In addition, we aim to account for subcortical language functions in terms of contemporary language production models (for instance Levelt, 1999). The case of OTM is also particularly relevant to the status of dynamic aphasia as a language specific disorder and on whether functionally distinct sub-varieties of this syndrome exist, as has been suggested by Robinson et al. (2005, 2006).

#### CASE REPORT

OTM is a 67-year-old man, right-handed, with 8 years of education, who had retired from work as a solderer. In May 2005 he suffered from an ischemic stroke. A CT scan revealed a lesion involving the left basal ganglia, the corona radiata, and the surrounding white matter. Within the basal ganglia the lesion involved the putamen and extended to the capsule close to the dorsal caudate (see Figure 1). A few days after his admittance to the Department of Neurology of the Ospedali Riuniti in Trieste he had a second stroke, this time concerning the right parietal lobe. When he was discharged he was referred for a neuropsychological evaluation. The testing was carried out at the Neuropsychology Laboratory of the Ospedali Riuniti in Trieste over a series of sessions that took place between September and October 2005.

#### Neuropsychological assessment

The patient was given a general neuropsychological assessment in September 2005 (see Table 1). He obtained similar values on the WAIS-R (Wechsler, 1981) Verbal and Performance IQs. OTM's Verbal IQ was in line with those obtained by previous dynamic aphasic patients (Costello & Warrington, 1989; Robinson et al., 1998, 2005), while his Performance IQ was in line with that of patient ANG (Robinson et al., 1998) and close to another case (Costello & Warrington, 1989), but considerably lower than that of CH (Robinson et al., 2005). One of the most striking results on the WAIS-R, was OTM's very poor performance on the Picture Arrangement task. That OTM's anterograde memory may be mildly impaired is suggested by his performance on a short story recall (Novelli et al., 1986). As far as attentional functions were concerned, selective attention was severely impaired (Attentive Matrices, Spinnler & Tognoni, 1987). Interestingly, OTM made many perseverations in this test as the targets for the first and second matrix were frequently incorrectly selected in the third matrix.

#### Frontal executive functions

The patient was administered a series of tests sensitive to frontal executive dysfunction (see Table 2) that revealed severe deficits on this cognitive domain. He was tested on the Modified Card Sorting test (MCST, Caffarra, Vezzadini, Dieci, Zonato, & Venneri, 2004) using the administration procedure described by Nelson (1976). The MCST is a shortened version of the original Wisconsin Card Sorting Test (WCST), in which only 48 items are employed, with excluded ambiguous stimuli that can be classified according to more than one category. OTM performed very poorly on this test completing only two categories; he was also highly perseverative in this test (14 errors were perseveration). OTM was also impaired on both phonemic (Carlesimo, Caltagirone, & Gainotti, 1996) and semantic verbal fluency tests (Spinnler & Tognoni, 1987).

OTM was administered a card version of the Stroop test (Barbarotto, Laiacona, Frosio, Vecchio, & Farinato, 1998). This consisted of 3 cards, each with 100 stimuli, organized in 10

 TABLE 1

 Patient OTM's results on the general neuropsychological assessment

Tests	Raw scores	Normative data $(Mean \pm SD)$	Cut offs
WAIS-R:			
Verbal IQ	83		
Digit span*	7		
Vocabulary*	6		
Arithmetic*	8		
Similarities*	8 9		
	85		
Performance IQ			
Picture completion*	9 5		
Picture arrangement*			
Block design*	8		
Object assembly*	8 QI-101		
TIB <sup>a</sup>	QI=101		
LANGUAGE:			
Aachner Aphasiae Test (A	AAT) <sup>b</sup>		
Token test	13/50	$2.0 \pm 2.3$	
Repetition	129/150	$147 \pm 3.2$	
Comprehension	103/120	$110 \pm 8.4$	
Reading/Writing	80/90	$87.2 \pm 4$	
Naming	108/120	$114 \pm 4.3$	
Non Literal Language Co	mprehen	sion <sup>c</sup> :	
- Metaphoric Expression	24/40		average*
- Idiomatic Expression	22/40		average*
MEMORY			
-	5	4 (7 + 0.05	~2 75
Spatial Span – Corsi test <sup>d</sup>		$4.67 \pm 0.95$	≤3.75
Short story recall <sup>e</sup>	7	$12.41 \pm 3.28$	≤8
Recognition memory test		22.0 + 1.0	
Short Recognition	24/25	$22.8 \pm 1.9$	
Memory Test for			
Faces <sup>f</sup>		40.0.4.0	
Recognition Memory	41/50	$40.9 \pm 4.8$	
Test for Words <sup>g</sup>			
LOGICAL FUNCTIONS	5:		
Coloured Progressive	25/36	$27.22 \pm 5.59$	≤18.96
Matrices – CPM <sup>h</sup>			
ATTENTEN			
ATTENTION:	24160	10.26 + 0.55	-21
Attentive Matrices <sup>i</sup>	24/60	$48.36 \pm 8.55$	≤31
VISUAL PROCESSING	:		
Screening test	19/20	$19.92 \pm 0.33$	≤15
(VOSP) <sup>1</sup>			
Object Decision	17/20	$17.7 \pm 1.9$	≤14
(VOSP)			
IDEOMOTOR APRAXI	. ,	N. IMAN CO	-50
AIM test <sup>m</sup>	64/72	No IMA $> 62$	<53
		Borderline	
		53-62	

The **bold** character indicates pathological scores. \*Age-scaled scores; <sup>a</sup>Brief Intelligence Test, Sartori et al. (1995); <sup>b</sup>Luzzatti et al. (1996); <sup>c</sup>Papagno et al. (1995); <sup>d</sup>Spinnler and Tognoni (1987); <sup>e</sup>Novelli et al. (1986); <sup>f</sup>Camden Memory test, Warrington (1996); <sup>g</sup>Warrington (1984); <sup>h</sup>Carlesimo et al. (1996); <sup>i</sup>Spinnler and Tognoni (1987); <sup>l</sup>Warrington and James (1991); <sup>m</sup>De Renzi et al. (1980).

Tests	Raw scores	Normative data (Mean ± SD)	Cut offs	
EXECUTIVE FUNCTIONS:				
WCST- Nelson's modified version <sup>a</sup>				
<ul> <li>n. of Categories</li> </ul>	2/6	Normal range: 4 – 6	<3	
<ul> <li>n. of Perseverative Errors</li> </ul>	14	Normal range: $3 - 0$	≥6.40	
Stroop Test <sup>b</sup>	Failed			
Brixton Test <sup>c</sup>				
- Standard (num of correct)	36/55 SS = 5	SS = 5 moderate aver.		
Cognitive Estimates <sup>d</sup>	Pass			
– Absolute error score	15	$10.81 \pm 3.71$	18	
<ul> <li>Total bizarreness</li> </ul>	2	$1.42 \pm 1.31$	4	
Trail Making Test <sup>e</sup> :				
– Trail A	Time = 45"	$67.26 \pm 28.69$	≥94	
– Trail B	Time = 210"	$167.54 \pm 97.41$	≥283	
Verbal Fuency (FAS) <sup>f</sup>	10	$30.77 \pm 11.09$	≤17.35	
Semantic Verbal Fluency <sup>g</sup>	10	2011,1 = 11103	_1,100	
– Animals	11			
– Fruits	5			
– Colors	8			
– Cities	9			
Total score	33/4 = 8.25	$16.76 \pm 4.38$	≤ 7.25	

 TABLE 2

 Patient OTM's results on frontal executive tests

The **bold** character indicates pathological scores. <sup>a</sup>Caffarra et al. (2004); <sup>b</sup>Barbarotto et al. (1998); <sup>c</sup>Burgess and Shallice (1996); <sup>d</sup>Della Sala et al. (2003) (original version by Shallice & Evans, 1978); <sup>e</sup>Giovagnoli et al. (1996); <sup>f</sup>Carlesimo et al. (1996); <sup>g</sup>Spinnler and Tognoni (1987); a raw score of 8.25 indicates mild impairment in this test.

columns and 10 rows. The patient was requested to scan each card from the left and having to give the appropriate responses as quickly as possible. The first card contained 5 colour words (red, blue, green, brown, and violet) and OTM was asked to read all words aloud. The second card consisted of squares and he was asked to name the colours of the squares. Finally, the third card displayed the names of the 5 colours printed in a conflicting ink colour. OTM had to name the ink colour of the printed words. The patient promptly and correctly read the words of the first card and reported the colours of the squares of the second card. For the third card the number of correct responses in the fixed time of 30 s was recorded following Barbarotto et al.'s procedure (1998). OTM performed very poorly on this card being able to name correctly only 2 words in the first 30 s.

In contrast to his poor performance on the Stroop, MCST, and fluency tests, OTM performed at average level in the standard version of the Brixton test (Burgess & Shallice, 1996), and he passed both the Cognitive Estimates Test and the Trail Making Test (see Table 2).

#### Language baseline

OTM was assessed on a wide range of language tests from the Italian version of the Aachener Aphasie Test (AAT, Luzzatti, Willmes, & De Bleser, 1996; see Table 1). He showed a mild deficit on the Token Test and in repetition of sentences. For the Token Test, OTM's understanding of simple verbal commands was intact. Errors (13/50) were made only in the most difficult subtests of the test, when he was required to retain two characteristics of the tokens at a time (i.e., shape and colour, colour and size). Errors (21/150) in repetition of sentences were characterized by omissions of 1 or 2 words when asked to repeat long sentences. Repetition of words was within normal limits. On the comprehension subtests his performance was within the normal range. In addition his reading, writing and naming skills were normal, as well as comprehension of metaphors and idioms (Papagno et al., 1995; see Table 1).

#### Speech production

OTM's spontaneous speech was greatly reduced; he could produce only short phrases of 3–4 words.

Family members claimed he tended not to speak at home, while before the stroke he had been very loquacious. He showed mild disprosodia and mild articulatory problems. When asked to speak, he was very often unable to communicate what he appeared to want to say, and he usually stopped in the middle of a sentence. When asked to describe something (i.e., what he remembered of his first stroke) his answers were characterized by many repetitions, interruptions and circumlocutions. For example, when asked to describe how he felt after his stroke he produced the following: meglio . . . ma più di tanto non so come parlar . . . non so come parlar . . . parlo un pò con mia moglie . . . ma più di tanto . . . (50 s) (I feel better . . . but I do not know how to speak . . . I do not know how to speak . . . I speak a *little with my wife* . . . *but not so much* . . . ).

OTM's speech was also analysed using tasks that elicited speech from pictorial stimuli. In order to obtain a spontaneous speech sample we asked OTM to generate a story from three simple pictures taken from the BADA (Battery for the Assessment of Aphasic Deficits, Miceli, Laudanna, Burani, & Capasso, 1994). He was given 1 min to produce a story for each picture. OTM was also asked to talk about both his job when he worked and the city where he lives. One minute was again given for each topic. Five Italian control subjects matched to OTM for age, education, and gender carried out the same tasks (see Table 3 for their performance and for comparison with OTM). The modified *t*-test of Crawford and Garthwaite (2002) was used to contrast the performance of OTM with that of control subjects. OTM produced significantly less words than controls when he was required to speak about his job and his city, whereas there was only a trend towards a difference between OTM and controls on the story generation task. Globally OTM produced less words (word/minute ratio; see Table 3) than normal subjects but he was close to the rate of word production of other dynamic aphasic patients. OTM always began the story generation task providing good descriptions of the pictures he saw. Only rarely did he attempt to construct a story as required. By contrast, controls provided less detailed descriptions but tried to produce a story for each single picture. These behaviours could be the reason why OTM did not differ from controls in the story generation task while doing so when asked to describe, for example, his city. In this latter task, stimuli (i.e., describe your city) provide less constrains for verbal production relative to pictures which act as cues for production in the story generation task.

### Summary

In sum, OTM showed impairments in intellectual, language, and executive functions as well as having problems in verbal memory and selective attention. Within the language domain OTM had a dissociation between dramatically reduced spontaneous propositional speech and either preserved or only mild impaired use of language in comprehension and naming skills. The diagnosis derived from the AAT (Luzzatti et al., 1996) was that OTM was not affected by aphasic disturbances. However, his dysphasic impairment falls within the classification of pure dynamic aphasia (Luria, 1970, 1973; Robinson et al., 2005, 2006).

The next experimental series of tests was designed to investigate OTM's language output disorder.

### WORD AND SENTENCE LEVEL GENERATION TASKS

The aim of this experimental series of tests was to pinpoint the nature of OTM's word and sentence level generation impairment. Most of the tests

TABLE 3
Speech rate of patient OTM, five matched controls, and four other dynamic aphasic patients

	ОТМ	Controls	T(4)	$ANG^{a}$	$MP^b$	$CH^c$	KAS <sup>d</sup>
Story generation $(3 \times 1 \text{min})^{\#}$	50	$130.2 \pm 45.15$	-1.62				
Event description $(2 \times 1 \text{ min})^{\#}$	39	$169 \pm 47.5$	-2.5				
Speech rate (words per min)	17.8	$59.8 \pm 17.63$	-2.17	29.2	<20	12.0	23.0

The total number of words produced are reported in each cell. The standard deviation for controls is also reported.

<sup>#</sup>See text for details on these tests. The **bold** character indicates significant differences between controls and OTM.

<sup>a</sup>Robinson et al. (1998); <sup>b</sup>Raymer et al. (2002); <sup>c</sup>Robinson et al. (2005); <sup>d</sup>Robinson et al. (2006).

were based on those used by Robinson et al. (1998, 2005, 2006). In addition others based on those of Costello and Warrington (1989) and Warren et al. (2003) were used. For comparison purposes OTM's performance in each test was contrasted with that obtained from another sample of five age-, gender-, and education-matched controls. As reported above, the modified t-test of Crawford and Garthwaite (2002) was used to make comparisons where needed. Where necessary, reaction times were calculated from a tape recording. Reaction times were defined as the time between the end of the stimulus and the onset of a response.

### Generation of sentences from single common words and single proper nouns (Robinson et al., 1998)

Single common words and single proper nouns were given one at time to OTM who was asked to produce a whole sentence incorporating the target word. Both the responses of patient OTM and those of control subjects are reported in Table 4 (the performances of patients ANG, CH and KAS, of Robinson et al., 1998, 2005, 2006, respectively, are also included in the table).

Remarkably, OTM produced sentences with the same structure for 7 of the 12 common words and for 8 of the 12 proper nouns. Despite his tendency to produce sentences with the same structure, the sentences OTM generated were always grammatical and meaningful. Hence, he globally produced 8/12 and 10/12 correct sentences from, respectively, common words and proper nouns. Control subjects performed at ceiling in this task. OTM's performance did not differ from that of controls on either kind of stimuli (p > .09 for both comparisons – common words, proper nouns). Moreover he did not show any significant difference across the 2 task conditions (OTM common words vs. OTM proper nouns,  $\chi^2(1) = 0.22$ , p = .64).

With common words he provided an explanation of function (e.g., '*Il tavolo serve per mangiare*' – 'The table is needed for eating' – for the word '*Tavolo*' – 'Table'). Two sentences of this group were correct but OTM initiated them only after very long pauses (>13 s), while he did not produce anything at all when given 2 other words. With proper nouns OTM used the expressions '*bellissimo*'

 TABLE 4

 Word and sentence generation tasks: summary of correct responses on each task of patients

 OTM, ANG, CH, KAS and control subjects

	Number correct					
	ОТМ	ANG <sup>a</sup>	$CH^b$	KAS <sup>c</sup>	Controls	
Generation of sentences from						
a. Common words	8/12	11/28	10/30	14/15	12/12	
b. Proper nouns	10/12	26/28	22/30	15/15	12/12	
Generation of sentences from						
a. Pairs with strong association	23/30*	22/30	NT	15/15	30/30**	
b. Pairs with weak association	13/30	4/30	NT	15/15	30/30**	
Generation of single words to complete sentences						
a. High predictability	19/20*	NT	NT	NT	20/20	
b. Low predictability	10/20	NT	NT	NT	20/20**	
Generation of phrases to complete sentences						
a. High predictability	17/20*	9/12	19/22	10/10	20/20	
b. Low predictability	10/20	3/12	11/22	10/10	20/20**	
Elaboration of nuclear sentences	2/10	3/20	NT	5/5	10/10**	
Sentence construction task	9/10	14/15	9/10	8/10	10/10	
Generation of a sentence given a pictorial scene	10/10	34/34	20/20	15/15	10/10	
Generation of a sentence from a single picture	2/20	0/6	NT	9/10	20/20**	

\*Indicates significant differences (p < .05) across the two conditions of the relative test for patient OTM.

\*\*Indicates significant differences (p < .05) between OTM and control subjects in the test. NT=not tested.

An arbitrary cut-off of 10 s was adopted for all the tests reported in this section; responses generated after this time were excluded by the analyses.

<sup>a</sup>Robinson et al. (1998); <sup>b</sup>Robinson et al. (2005); <sup>c</sup>Robinson et al. (2006).

and 'bravissimo' ('very beautiful and very good') (e.g., 'Pippo Baudo' prompted 'Pippo Baudo e' un bravissimo conduttore' -'Pippo Baudo is a very good showman'). For two of these stimuli he did not make any attempt to produce a sentence.

Clearly, OTM did not have problems in generating a response in this task; however he appeared to use a compensatory strategy in coping with task demands (explain function for common words and report a description for proper nouns). Thus, when he was asked to vary the structure of the sentences he was producing, he complained that the task was too difficult and that he did not have any other word in mind. Moreover, OTM may have perseverated on this test, as have other patients with subcortical lesions when tested on similar tasks (Esmonde, Giles, Xuereb, & Hodges, 1996; see also patient MP, Raymer et al., 2002, for strategy use). OTM performed this task differently by ANG and CH who had more difficulties in generating sentences from common words than from proper nouns. As stated also in Robinson et al. (2006), proper nouns are associated with a dominant response or with few verbal response options, while common nouns tend to elicit many response options.

### Generation of a sentence from word pairs with strong and weak associations (Robinson et al., 1998)

The stimuli used in this task were the same of those of Robinson et al. (1998). They consisted of strongly associated word pairs (e.g., 'giraffa-collo', 'giraffeneck') and weakly associated word pairs (e.g., 'bambino-dolce', 'baby-sweet'). OTM was asked to produce a sentence incorporating both words of the pair. As for patient ANG, OTM had more difficulties in producing sentences from weakly associated word pairs than from strongly associated ones ( $\chi^2(1) = 5.62$ , p < .02) (see Table 4). Control subjects had no difficulty with this task.

### Generation of single words to complete sentences with high and low response predictability (Robinson et al., 1998)

This task consisted of 20 sentence frames to be completed with a single word where there were few response options (e.g., 'The boy sent the letter without the . . .' with 'stamp' being the selected response for 98% of the subjects; (Bloom & Fischler, 1980; 'Il ragazzo spedì la lettera senza'. . . 'francobollo', is the Italian version) and also 20 sentences which had many response options (e.g., 'The policeman had never seen a man so . . .' with 'drunk' being the most often selected response, 18% of the subjects; 'La polizia non aveva mai visto un uomo così...', is the Italian version). The sentences given to the patient were an Italian translation of either the corresponding sentences used in a previous study with a dynamic aphasic patient (Robinson et al., 1998) or of the sentences of Bloom and Fischler (1980).

OTM produced appropriate responses (in less than 2 s on average) for almost all the sentences with high response predictability (with low competition in the response set). By contrast his performance was significantly impaired on the low response predictability sentences (with high competition in the response set) ( $\chi^2(1) = 8.02, p < .006$ , see Table 4). Control subjects performed at ceiling in this task.

### Generation of phrases to complete sentences with high and low response predictability (Robinson et al., 1998)

This task consisted of sentence frames, based on those of Robinson et al. (1998), to be completed by the addition of a whole phrase. Twenty had few plausible verbal response options for their completion (e.g., 'The hairdresser moved next to the lady with her scissors and . . .'; 'La parruchiera ando' verso la donna con le forbici e . . .', is the Italian version) while 20 sentences had many plausible verbal response options for their completion (e.g., 'The man sat in his chair and . . .'; 'L'uomo si sedette sulla sua poltrona e . . .' is the Italian version). Each sentence was read to the patient. As for patients ANG and CH, OTM produced significantly more phrases in completing sentences with a highly predictable response (the mean voice onset time for the correct responses was 2.8 s) than in case of sentences with low predictability of the response (mean voice onset time 3.2 s;  $\chi^2(1) = 4.10$ , p < .05) (see Table 4). Controls perform at ceiling on this task.

### Elaboration of nuclear sentences (Warren et al., 2003)

OTM was presented with 10 complete sentences and asked to produce a second sentence developing

the theme of the first. OTM did not provide any answer for 3 out of 10 sentences. For five sentences OTM provided only a completion without generating a separate sentence (e.g., for the sentence: '*La ragazza ascoltava la storia*...', 'The lady was listening to the story ...', after more than 15 s he said '*del suo ragazzo*', 'of her boyfriend'). For the remaining two sentences OTM produced a correct response. Controls had no difficulty with this task.

### Sentence construction task (Costello & Warrington, 1989)

Dynamic aphasia can also be present in the context of concomitant syntactical or verbal planning impairments. OTM was provided with 10 sentences of 4 to 8 words in length which had to be rearranged. Single words were printed on separate pieces of paper and had to be reorganized to construct a meaningful sentence. OTM performed well in this task (9/10). His only hesitation concerned one of the two 7-word sentences. He rearranged the target sentence: 'Ieri Luca ha rotto la sua macchina nuova' ('Yesterday Luca broke his new car') as 'Ieri Luca ha rotto sua la macchina nuova'. Insofar as this task is one of verbal planning (Costello & Warrington, 1989) this ability was shown to be spared in OTM. Controls also had no problem in this task (see Table 4).

### Generation of a sentence given a pictorial scene (Robinson et al., 1998)

As shown in Table 4 previous studies with dynamic aphasics had found that patients were able to provide simple descriptions of pictorial scenes. In this test OTM was given a series of pictures taken from the BADA (Miceli et al., 1994) and was told to create a sentence that described the content of the picture. The patient was able to do this for all the pictures he saw (10/10). Controls also performed errorless in this task.

# Generation of a sentence from a single picture (Robinson et al., 1998)

Patient ANG (Robinson et al., 1998) was impaired when asked to produce whole sentences (i.e., more than a simple description) that incorporated the meaning of single pictures with which he was presented. OTM was presented with 20 single pictures selected from the BADA battery (Miceli et al., 1994) and required to produce a whole sentence incorporating the meaning of the picture, but not to simply describe it. Pictures were divided in two groups: 10 were of objects whereas 10 were of either persons or animals doing an action. The pictures from the two groups were presented at two different times. Like patient ANG, OTM's performance was seriously impaired in this test (only 2 out of 20 sentences were correct). In most cases, OTM merely produced a description of the picture rather than generating a whole sentence as required. Controls performed at ceiling (see Table 4).

### Summary and conclusions from the word and sentence generation tasks

The word and sentence level generation tests showed that OTM has difficulties in generating words, sentences and phrases. However, in certain cases he was able to produce plausible words and phrases. OTM was particularly impaired when stimuli activated many response options (phrases and words low in response predictability, word pairs weak in association). By contrast he generally performed much better with stimuli that strongly constrained a response (phrases and words high in response predictability, word pairs strong in association). In these respects OTM's performance resembled those of the dynamic aphasic patients ANG and CH (Robinson et al., 1998, 2005). The results from this series of tests showed that OTM had problems in generating verbal messages in condition of high competition between multiple response options. However, OTM behaved differently from ANG or CH in some ways. Qualitatively he performed just in the normal range in the generation of sentences from proper nouns and common words. Nevertheless, as reported above, he appeared to use a compensatory strategy in this task.

Gold et al. (1997) reported the case of patient CO who also became dynamic aphasic following a basal ganglia lesion, namely a bilateral striatocapsular infarction. CO also presented with signs of executive dysfunction. CO performed poorly on a semantic categorization task and on a procedural discourse test. The authors argued that he suffered from an impairment of concept formation as well as from defective semantic strategy formation. They held that the latter problem was confirmed by the difficulty the patient had in sorting items from very closely related categories by contrast with his intact performance in sorting items from more distantly related categories. Gold et al. (1997) suggested that CO's deficits might reflect a more general impairment in the ability to organize knowledge in a hierarchical fashion. The following section aims to assess whether OTM's problems in producing verbal responses in situations of high competition may be due to deficits in concept generation and in semantic strategy formation.

### ROUTINE ACTIVITIES DESCRIPTION AND SEMANTIC STRATEGY FORMATION

# Procedural discourse task (Gold et al., 1997)

In Gold et al.'s (1997) version of the task the patient had to describe the steps involved in carrying out a series of common actions such as preparing a cup of coffee. The patient performed the task in two conditions. First he described the steps involved in the procedures without any prompting, whereas in the second the experimenter provided the patient with cues such as 'the first step is . . .' etc.

We administered a similar task to OTM but changing some of the required actions to fit with those used by Rumiati, Zanini, Vorano, and Shallice (2001). These authors provided a list of the verbal descriptions of the discrete steps involved in a series of multi-objects-actions (MOT) that they administered to their apraxic patients. They distinguished a total of 47 steps for 10 common tasks with 7 tasks being divisible into 5 discrete steps and 3 tasks into 4 steps. The procedures were: Preparing orange juice, Making coffee using a coffee pot, Lighting a cigarette, Preparing a letter for posting, Pouring water from a bottle, Lighting an electric torch, Hanging a small picture, Lighting a candle, Sharpen a pencil, Peeling a potato.

OTM was asked to describe the steps he usually goes through in carrying out these actions. He performed as well as normal subjects (n = 5)in this task. OTM gave an average of 3.9 steps for each action while controls gave descriptions formed of 4.3 steps on average with the difference being not significant (t(4) = -0.97; modified *t*-test, Crawford & Garthwaite, 2002). Given OTM's ability to perform the task he was not administered the sequence cued condition used by Gold et al. (1997).

### Semantic categorization task (Gold et al., 1997)

Before assessing OTM's abilities in semantic strategy formation and semantic categorization, we evaluated his ability to access semantic representations. OTM was tested using only the picture section of *The Pyramids and Palm Trees Test* (Howard & Patterson, 1992), a test specifically aimed to assess the integrity of the semantic network. His performance was well within the normal range and almost at ceiling (50/52) indicating that he could recognize the items and retrieve conceptual and semantic information about them.

Given that OTM's ability to access meaning from pictures was intact we gave him a semantic categorization task. We used the procedure developed by Robinson et al. (2005) and the categories these authors employed. They had found that the dynamic aphasic patient CH was unimpaired in this task. OTM was required to sort items into two categories. A set of 80 words and a set of 80 pictures were chosen. Each of the two groups of stimuli formed 16 categories, each consisting of five highly associated items. Pairs of categories were used with their degree of association being either distant or close. OTM was given 10 cards at the same time and was required to sort the pictures or the words into two groups of five each. In one condition the names of the two categories were given in advance to the patient (cued condition) and in another the names of the categories were not given (uncued condition).

OTM's performance on this task is reported in Table 5 together with CH's performance (Robinson et al., 2005) and that of four control subjects who were administered the task. OTM's performance on the task was good and similar to that of CH (Robinson et al., 2005) and of normal controls. OTM was only somewhat slower than controls in the uncued condition of the closely related word pairs category (t(3) = 2.88, p < .05).

### Summary and conclusions from the procedural discourse and the semantic categorization tasks

Given OTM's intact performance on the procedural discourse task, an explanation of his deficits

		Pictures				Words			
	Cle	ose	Distant		Close		Distant		
Condition	N. Correct	Mean RT	N. Correct	Mean RT	N. Correct	Mean RT	N. Correct	Mean RT	
Cued									
OTM	40/40	12	40/40	10	38/40	23	40/40	18	
CH <sup>a</sup>	39/40	28.3	40/40	25.5	40/40	18.8	40/40	20	
Controls	40/40	13 (2.2)	40/40	11.5 (1.9)	39/40	15 (3.9)	40/40	14.2 (4.3)	
Uncued									
OTM	38/40	25	40/40	13	35/40	44	40/40	18	
CH <sup>a</sup>	38/40	47	40/40	28.3	37/40	34.8	40/40	19.3	
Controls	38.2/40	26.2 (7.1)	40/40	16 (7.7)	37/40	22.75 (6.6)	40/40	16.5 (3.8)	

 TABLE 5

 Semantic categorization task

Response times are expressed in seconds. Standard deviations for controls are shown in parentheses. <sup>a</sup>Robinson et al. (2005).

in terms of impaired generation of concepts can be ruled out. OTM was able to retrieve information in order to generate phrases for describing well learned actions. OTM performed very differently from Gold et al.'s patient in this test. The results of the semantic categorization task showed that OTM did not have a semantic strategy formation deficit of the kind proposed by Gold et al. (1997) to account for the difficulty their patient showed on the task. In this respect the findings on OTM are similar to those on patient CH (Robinson et al., 2005).

### RANDOM NUMBER GENERATION TASK (ROBINSON ET AL., 2005)

In this task OTM's ability to generate numbers was investigated. As discussed in Robinson et al. (2005; see also Cappelletti, Butterworth, & Kopelman, 2001), numbers are a special category which can dissociate from other linguistic categories. Dynamic aphasic patient CH (Robinson et al., 2005) had performed in the normal range on this task. The task that we used consisted of three conditions differing in the size of the response set. In the first part of the task OTM was asked to generate numbers within the set 1-9 in a random order. In order to illustrate the concept of randomness, both the control subjects and patient OTM were given the analogy of picking a number out of a hat, reading it aloud, putting it back, and then picking another. The number set 1-9 was followed by two conditions in which the response set was more restricted, OTM having to generate numbers from the sets 1-4 and 1-2. Each condition involved 100 numbers. OTM had to generate a

number in time with a tone occurring once every 3 s, as used by Robinson et al. (2005). The percentages of number repetitions (e.g., the series 2–2 was scored as 1), descending series (e.g., 4–3, scored as 1) and ascending series (e.g., 3–4, scored as 1; or 3–4–5, scored as 2) were calculated.

OTM's performance is reported in Table 6 along with that of control subjects. For comparison purposes performance of patient CH is reported as well. OTM performed significantly different from control subjects in each kind of response for the 1–2 number set. In the number set 1–4 OTM produced significantly more descending series than did the controls. In the largest number set (1–9) OTM produced more responses that were part of ascending series than control subjects.

### Summary from the random number generation task

The random number generation task showed that OTM differed from normal controls particularly in the length of ascending and descending series he generated. This behavior was not related to the size of the response set since differences between OTM and controls were present in all conditions of the task. In the Discussion, it will be argued that, in the SAS framework of Norman and Shallice (1986), OTM's abnormal generation of ascending and descending series of numbers may reflect a failure of the SAS to inhibit strong routine schemata within the contention scheduling (i.e., counting in ones) in favor of switching schemata as is necessary to accomplish the random number

Random number generation task							
Number generation task	Chance % Responses	OTM % Responses	Controls % Responses	t (4)	CH <sup>a</sup> % Responses		
Number set (1–2)							
Repeats	48	36.5	51 (4.33)	*-3.05	48		
Ascending series	25	32	25 (2.77)	*2.31	28		
Descending series	25	31.2	24 (1.2)	*5.47	23		
Number set (1–4)							
Repeats	25	0	11.2 (7.72)	-1.32	30		
Ascending series	18.75	33.7	22.2 (5.54)	1.89	21		
Descending series	18.75	33.7	21 (4.63)	*2.50	25		
Number set (1–9)							
Repeats	11.1	0	2 (1.9)	-0.96	2.5		
Ascending series	9.9	20.4	8 (4.78)	*2.36	24		
Descending series	9.9	23.4	17 (5.16)	1.13	13.5		

 TABLE 6

 Random number generation task

\*Indicates significant t values (p < .05) for comparison between OTM and controls.

Responses are reported as percentage. Standard Deviations for controls are shown in parentheses.

<sup>a</sup>Robinson et al. (2005).

generation task. Excessive use of ascending and descending sequences of numbers have also been reported in the context of TMS involving the left dorsolateral prefrontal cortex (Jahanshahi et al., 1998) and, as noted also by Robinson et al. (2005), this may indicate an associated deficit for OTM.

### NONVERBAL GENERATION TASKS

Robinson et al. (2005) described the dynamic aphasic patient CH who was found to have largely preserved abilities to give non-verbal responses, performing as well as normal controls in some non-verbal generation tasks. This was taken as evidence that CH's dynamic aphasia did not extend beyond the domain of language. The next session aims to asses whether OTM's generation deficit too did not extend to cognitive domains other than language. Two of the tests used by Robinson et al. (2005) were chosen: figural fluency (Five-Points test), and motor movement generation.

### Five-points test: A figural fluency test (Lee, Strauss, Loring, McCloskey, & Haworth, 1997)

The five points test is a measure of non-verbal figural fluency. A subject is presented with a sheet of paper that consists of 40 five-dot matrices arranged in 8 rows and 5 columns. The subject is required to connect the dots in as many different

ways as possible. Lee et al. (1997) found that patients with frontal lobe dysfunction made many more perseverative errors than nonfrontal neurological and psychiatric patients. Frontal lobe patients produced about 25 designs with 27% perseverations on the 3-min version which we used. By contrast, the dynamic aphasic patient CH (Robinson et al., 2005) drew 20 different designs without making any perseveration.

OTM did not significantly differ from control subjects in the total number of designs produced. OTM produced 15 designs while control subjects drew a mean of 16.6 designs on average (t(4) = -0.39; modified *t*-test, Crawford & Garthwaite, 2002). However, considering only the number of novel designs produced, OTM performed clearly worse than normal controls (6 vs. 13.8, respectively, t(4) = -6.5; p < .001). In fact OTM made 9 (60%) perseverative errors while controls made only 2.8 (16%) perseverations on average, the difference being highly significant (t(4) = 5.16; p < .005, modified *t*-test, Crawford & Garthwaite, 2002). OTM's performance on this test was extremely poor showing a clear impairment of perseveration in figural fluency.

### Motor movement generation (Robinson et al., 2005)

In this test OTM was provided with a joystick which could be moved in four directions: right, left, up and down. OTM was requested to select a movement using the joystick whenever he heard a sound that occurred once each 3 s. He was told that the movements did not have to reproduce a schema or a pattern. Owing to his right hemiplegia OTM moved the joystick with his left hand. The task was divided into three conditions according to the number of movement options he could select. In the first two conditions OTM could select between two movement options, either Left (L) and Right (R), or Up (U) and Down (D); in the third condition there were four movement options: U, D, L, R. As in Robinson et al.'s (2005) study, each condition lasted 4 min. OTM was familiarized with the task by performing a baseline condition of 2 min in which he had to move the joystick in one direction (U) in time with the sound (once each 3 s). The percentages of repeated responses (e.g., L-L) and opposite responses (e.g., L-R) were calculated in order to have measures of fixed or random responses.

Table 7 reports OTM's results together with those of CH and control subjects. No t values (modified t-test, df=4; Crawford & Garthwaite, 2002) reached significance when OTM's performance was compared with that of control subjects.

### Summary and conclusions from the non-verbal generation tasks

OTM's performance on the non-verbal generation tasks varied across tasks. OTM has normal performance in the motor movement generation task while he was impaired in the figural fluency test. Although OTM did not differ from normal controls in the number of total responses generated in this test, he produced a small number of novel designs and he made many more perseverations than controls.

#### GENERAL DISCUSSION

OTM presented with abnormally reduced propositional language following an ischemic stroke to the left basal ganglia. OTM's language production was characterized by reduced fluency particularly in situations requiring more than a simple description of the stimulus. His reduced spoken language was not connected to general deficits in reading, repetition, naming or comprehension, as these skills were either preserved or only mildly impaired. OTM could only produce short phrases of 3-4 words and exhibited mild disprosodia and mild articulatory problems as well. Globally, this pattern of deficits is consistent with dynamic aphasia (Luria, 1970, 1973). Indeed, a quantitative evaluation of his speech rate showed that this was similar to those of other patients with dynamic aphasia. In addition to his language output disorder OTM presented with signs of executive dysfunction performing poorly in the Modified Card Sorting Task, phonemic and semantic verbal fluency and in the Stroop test.

A series of tasks was administered aimed at investigating OTM's language output disorder. Results from the word and sentence level generation

Motor movement generation task							
Motor movement Generation Task	Chance % Responses	OTM % Responses	Controls % Responses	<i>t</i> (4)	CH <sup>a</sup> % Responses		
Two options							
Left-Right							
Repeats	50	40	48.6 (6.54)	-1.19	42.9		
Opposites	50	60	51.4 (6.54)	1.19	57.1		
Two options							
Up-Down							
Repeats	50	51.3	52 (14)	-0.04	52		
Opposites	50	48.7	48 (13.7)	0.04	48		
Four options							
Up-Down-Left-Right							
Repeats	25	1.4	17 (8.45)	-1.68	38.8		
Opposites	25	36.6	33 (4.06)	0.80	23.8		
Other	50	62	50 (11.55)	0.94	37.4		

 TABLE 7

 Motor movement generation tas

Responses are reported as percentage. Standard deviations for controls are shown in parentheses. <sup>a</sup>Robinson et al. (2005).

tests showed that OTM had great difficulties when required to produce phrases and words; his problems became evident when stimuli did not suggest a dominant response. In a similar fashion to patient ANG (Robinson et al., 1998), OTM had more difficulties in producing sentences from word pairs with weak association between them than from a strongly associated word pairs and had also many more problems in completing low predictability sentences, either with phrases or words, than high predictability ones. In a similar fashion to ANG (Robinson et al., 1998) and CH (Robinson et al., 2005) but differently from ROH (Costello & Warrington, 1989), OTM did not show any problem in the sentence construction task. Tests of speech elicitation from pictures (generation of a sentence given a pictorial scene and from a single picture) produced similar results to those obtained in other dynamic aphasic patients (Robinson et al., 1998, 2005); indeed OTM was severely impaired in producing sentences from single pictures whereas he could give a simple description of them.

We also assessed whether OTM suffered from the same kind of deficits described by Gold et al. (1997) in their dynamic aphasic patient CO, who also had a basal ganglia infarction. These authors proposed that their patient suffered from deficits in semantic strategy formation and concept generation, being impaired in both tasks of semantic categorization and procedural discourse. OTM's performance in the latter task showed that he could correctly describe routine activities, he could generate concepts and combine them in sequences. OTM also performed almost errorless in the semantic categorization task as done by patient CH (Robinson et al., 2005). As discussed by Robinson et al. (2005), the fact that CH and OTM performed normally in the semantic categorization test indicates that they do not have a primary deficit in semantic strategy formation.

OTM's ability to generate numbers was also investigated. In a random number generation task he performed differently from control subjects producing more ascending and descending series of numbers. We interpret these findings as due to a failure of suppression of strong routine responses (i.e., counting in ones).

Non-verbal response generation skills were found to be preserved in 1 task; OTM was within the normal range in the motor movement generation task. His performance on figural fluency was however impaired; the number of responses was in the normal range but 9/15 of these were perseverations.

### Possible explanations of OTM's dynamic aphasia

As previously reported in the text, OTM also suffered from a stroke involving the right parietal lobe. Interestingly, there has been reported evidence showing that language performance may be influenced by the side of space to which subjects are paying attention. Thus spatial information may influence language functions. For instance, Coslett (1999) investigated the performance of several groups of patients on both motor and language tasks. He found that subjects with right parietal lesions performed better when they directed attention to stimuli in the right hemispace. The aim of our study was not to further assess whether spatial factors influence OTM's performance on language tasks. Nonetheless, OTM did not show any sign of neglect when, for instance, the tests which involve visual material in space (e.g., Progressive matrices) are considered. Moreover he did not have greater difficulties on the left than the right in tests which involve space such as Attentive Matrices. Accordingly, OTM's problems in generating responses when alternative options are available, and his high number of perseverative responses are more likely due to damage to fronto-striatal regions.

As briefly reported in the Introduction, a number of explanations have been proposed for forms of dynamic aphasia extending both within the domain of language and beyond the latter. As far as accounts of dynamic aphasia that consider the disorder within the domain of language are concerned, for reasons similar to those presented by Robinson et al. (2005) we can rule out the possibility that OTM's deficits lay in damage to a mechanism forming the linear scheme of a sentence (Luria, 1970, 1973). Similarly, the possibility of an impairment in verbal planning which Costello and Warrington (1989) considered for their patient (ROH) can be rejected for OTM. Our patient performed almost errorless in the sentence construction test on which ROH had great difficulties.

In addition to showing problems in both semantic categorization and procedural discourse tasks, patient CO (Gold et al., 1997) had been impaired in design fluency, category fluency tasks and also in some tests of frontal system functions, such as the Trail making B and Wisconsin Card Sort. Due to this empirical evidence, Gold et al. concluded that CO's deficit in propositional language could be attributed to associated deficits in executive functions. As already described, OTM was impaired in some tests of executive functions as well. OTM also showed difficulties in the short story recall (see Table 1), a task that might be strategy dependent, and also in the picture arrangement subtest of the WAIS (see Table 1).

As far as the word and sentence generation tasks are concerned, we have shown that the number of response options associated with a task (verbal response alternative options) was an important factor helping to give rise to OTM's performance in many of the tasks we used. In a similar fashion to CH (Robinson et al, 2005), OTM was not impaired when a stimulus strongly suggested a response. By contrast, OTM had great difficulties when stimuli activated many response alternatives. As stated in Robinson et al. (2005), a deficit in the selection of verbal responses in propositional speech is likely to be due to defective mechanisms of conceptual preparation (Levelt, 1989, 1999). Lexical concepts have sometimes to be generated in conditions of high competition, namely when many of them are simultaneously activated. These conditions are those that pose the greatest requirements to the conceptual preparation mechanisms, particularly when the latter are defective. The empirical evidence collected in this study suggests that OTM, similarly to patients ANG and CH (Robinson et al., 1998, 2005, respectively), suffers from an impairment in verbal response generation in situations of high competition.

However, differently from CH, OTM also had problems in figural fluency and in the random number generation task. OTM made many perseverations in the figural fluency test while he gave increased ascending and descending series of numbers in the random number generation task. As briefly reported previously in the text, we suggest that a deficit of inhibition can explain OTM's problems with numbers. Among other processes assumed to be involved in reasonable performance of the random number generation task, one consists of inhibiting the most familiar strategy of counting upwards or downwards in ones which, in the terminology of the SAS model, is the strongest schema in the contention scheduling. Thus it is possible that OTM's pattern of performance in this task reflects a failure of the SAS to inhibit strong routine schemata (i.e., counting in ones) in favor of less common actions (i.e., counting in twos). An account based on failure of suppression may also explain OTM's perseverative responses in the figural fluency task.

Nevertheless, an alternative possibility exists for explaining perseverations on figural fluency. Perseverations may reflect a deficit to generate novel content. We have shown that OTM was able to produce only 6 different figures relative to controls which generated almost 14 new designs in the figural fluency test. OTM's inability to generate novel content may also be seen to fit with his difficulty in some language tasks. For instance, OTM did not have any problem in producing a response when given common words or proper nouns; however, he appeared to perseverate or to use a compensatory strategy in this task (see also his problems in sentence generation from single pictures or elaboration of nuclear sentences in which novel material has to been generated).

In summary, we propose that two deficits contribute to the overall pattern of performance of patient OTM. An impairment of verbal response generation in conditions of high competition is present along with one of novel thought generation evidenced by perseveration and due to either failure of inhibition or inability to generate novel content. These two deficits may be related to damage of different regions within the fronto-striatal circuits, namely, left frontal regions and basal ganglia, as is argued in the next section.

As reported in the Introduction, Robinson et al. (2006) proposed a distinction between two subtypes of dynamic aphasia. Since discourse generation has not been specifically tested in OTM, it is difficult to say to which subtype his dynamic aphasia relates. We suggest that OTM has a similar impairment to the first subtype of dynamic aphasia in which a verbal generation impairment is present along with associated left frontal lesions. However, a profile related to the second subtype of Robinson et al. (2006) cannot be ruled out given that problems in response generation may be also present in domains other than language (figural fluency) in OTM.

#### Anatomical implications

The case of OTM, in a similar fashion to those of the dynamic aphasic patients CO and KAS (Gold et al., 1997; Robinson et al., 2006, respectively; see also Raymer et al., 2002), suggests that subcortical lesions which give rise to dynamic aphasia also lead to deficits in non-verbal domains. OTM's pattern of performance on both verbal and non-verbal tasks suggests that he suffered from two different deficits: impaired verbal response generation in situations of high competition and impaired novel thought generation as evidenced by perseveration.

With regard to the first deficit, there is a considerable body of neuropsychological and neuroimaging evidence supporting the role of the left inferior frontal gyrus (LIFG) in the process of conflict resolution, which is made by selecting information from among competing alternatives (Barch, Braver, Sabb, & Noll, 2000; Persson et al., 2004; Thompson-Botvinick, 2006; Thompson-Schill. Schill & D'Esposito, Aguirre, & Farah, 1997; Thompson-Schill et al., 1998; Zhang, Feng, Fox, Gao, & Tan, 2004). Recently, Badre, Poldrack, Paré-Blagoev, Insler, and Wagner (2005) have provided fMRI evidence supporting the fact that selection could be subserved by the left mid-ventro lateral prefrontal cortex (VLPFC) while controlled retrieval processes could be subserved by the left anterior VLPFC.

Referring back to dynamic aphasia, the literature suggests the involvement of the LIFG in this syndrome. As reported in the Introduction, both neurodegenerative and focal lesions have been seen to lead to dynamic aphasia. A review of these cases supports the role of the LIFG in the emergence of the reduced verbal output, which is generally observed in dynamic aphasic patients (Costello & Warrington, 1989; Esmonde et al., 1996; Raymer et al., 2002; Robinson et al., 1998, 2005; Snowden, Griffiths, & Neary, 1996; Warren et al., 2003). According to this evidence, the findings on OTM suggest that his verbal response generation impairment may be due to a frontostriatal damage disrupting the left frontal region function of selection in situations of high competition. Admittedly, a word of caution is necessary with regard to the CT scan: in fact this is not 100% sensitive for ischemic damage, so that the precise extent of the frontal lesion in OTM cannot be exactly defined.

As reported in the Introduction, there is evidence suggesting the involvement of basal ganglia in controlled cognitive processes (Copland, 2003; Copland et al., 2000a, 2000b; Crosson et al., 2003; Redgrave, Prescott, & Gurney, 1999). In particular, recent studies assign the basal ganglia a non-language specific role in the inhibition of competing alternatives (Castner et al., 2007, in press; Crescentini, Mondolo, Biasutti, & Shallice, 2008; Longworth et al., 2005). Different studies have proposed that deficits in the SAS may also reflect in poor performance on tasks requiring inhibition of prepotent or irrelevant responses. Lesions or malfunction of basal ganglia seem to be particularly important in causing failure of inhibition. As an example, Dujardin, Degreef, Rogelet, Defebvre, and Destee (1999) (see also Bouquet, Bonnaud, & Gil, 2003; Castner et al., 2007, in press; Crescentini et al., 2008 for similar findings) have shown that PD patients had problems in inhibiting task irrelevant information in a modified version of the Stroop test and of the Brown-Peterson paradigm. Moreover, in an fMRI study, Rossel, Bullmore, Williams, and David (2001) studied the brain correlates of automatic and controlled processing in a semantic priming environment. Automatic and controlled processing were investigated using, respectively, short and long prime-target delays. The authors found that the putamen was preferentially activated at long intervals and this led them to suggest a role for this structure in controlled semantic processes. The authors suggested that the putamen may be involved in the processes of response selection and inhibition. Even more recently, McNab and Klingberg (2008) have proposed that the basal ganglia operate to allow only task-relevant information into the working memory (see also Frank, Loughry, & O'Reilly, 2001). This would be possible through the selective filtering of this information.

The role of basal ganglia in the suppression of competing alternatives in the motor realm is well known (see Mink, 1996). Nevertheless, the studies briefly reported above suggest that Mink's framework can also be applied to domains other than motor behavior (i.e., semantic priming, word selection, cognitive inhibition, see also Crosson, Benjamin, & Levy, 2007).

Accordingly, we suggest that a failure of inhibition could explain the problems that OTM had in the random number generation task. Moreover, it is also a possible explanation for his perseverative responses.

From another perspective, it is now usually assumed that different areas of the frontal lobes project to separate areas of the striatum so that parallel frontal-subcortical circuits are formed (Alexander & Crutcher, 1990; Zgaljardic et al., 2006). Among these, the dorsolateral prefrontal circuit involves: Brodmann's areas 9- and 10-dorsolateral caudatepallidum, the substantia nigra-ventral anterior, the dorsomedial nuclei of the thalamus and the dorsolateral prefrontal cortex. The relevance of this circuit has been stressed by Gold et al. (1997) in order to account for several of the signs of frontal dysfunction shown by their patient. OTM also showed impairments which correspond to malfunctions of the dorsolateral prefrontal cortex. Moreover. the components of this circuit have been seen to be critically implicated in response suppression during the random number generation task (Brown, Soliveri, & Jahanshahi, 1998, Jahanshahi et al., 1998) and also during other tasks requiring challenging response inhibition such as the Stroop task (Alexander, Stuss, Picton, Shallice, & Gillingham, 2007). Furthermore, recent evidence shows that the basal ganglia may be implicated in each part of the two-process model (selection and controlled retrieval) of control of semantic memory proposed by Badre et al. (2005; see Longworth et al., 2005). Finally, that this could be the case has been confirmed more recently by further evidence collected on Parkinson's disease patients (Crescentini et al., 2008).

In sum we propose that an impairment to the basal ganglia, and the consequent abnormal functioning of subcortical-frontal circuits, are important factors in helping to give rise to the deficit of novel thought generation found in OTM and, more generally, to his pure dynamic aphasia.

### Conclusions

We report the case of OTM who presented with dynamic aphasia following a lesion to the left basal ganglia. We interpreted the pattern of performance of OTM as due to two deficits. The first concerns the ability to generate verbal responses and is particularly present when stimuli activate many competing response options. The second deficit consists of defective generation of novel thoughts as evidenced by perseveration. We hold the first deficit to arise from a frontostriatal damage disrupting the left frontal region functions, and the second from a damage to the basal ganglia.

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